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On-Board Measurements of Particle and Gaseous Emissions from a Large Cargo Vessel at different operating conditions

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Shipping-related emissions are one of the major contributors to global air pollution, especially in coastal areas (Viana et al 2014). An assessment published in 2010 (Eyring, et al 2010) found that over 70% of ship emissions have been detected up to 400 km inland and significantly contribute to air pollution in the vicinity of harbours. Moreover, shipping activities also significantly contributes to ocean acidification. Quantitative and qualitative estimation of pollutant emissions from ships and their dispersion are thus becoming more important.

The measurements were performed in October and November 2015 on a large cargo vessel at Port of Brisbane, Gladstone, and Newcastle. All measurements have been carried out on both main and auxiliary engines of the vessel for different operating conditions, experienced at berth, maneuvering, and at sea. Instruments were placed on a deck high up in the machinery room where the exhaust gas was sampled and measured continuously from two holes cut in the exhaust channel after the turbocharger of the main engine. From the first sampling point, the raw hot-exhaust gas was directed to a DMS 500MKII – Fast Particulate Spectrometer with a heated sample line, and two dilution system. The second sampling point was used for measurements by a Testo 350XL gas meter, and by a DustTrak II Aerosol Monitor (8530 TSI) and Sable CO_2 monitor connected after a Dekati ejector dilutor. Data on engine power, engine revolution, fuel oil consumption, and exhaust gas temperature were measured by the ship's instrumentation. The ship used HFO for both her main and auxiliary diesel engines. All of the measurements were grouped into 3 categories: Ocean-going, Manoeuvring and at Berth.

Particle number size distributions were measured in the size range of 5nm – 1.0µm with a sample frequency of 1 Hz. The particle mass emission factor (EF_{PM}), in the size range <1.0 µm, was calculated from the number concentrations measured with the DMS 500 assuming spherical particles with different densities for nucleation and accommodation mode. In addition, mass concentrations of PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ were also measured with a DustTrak.

The top figure shows the average particle number and mass size distributions for particles measured with the DMS500. The particle number size distributions observed only one mode for different operating conditions of the ship, with a peak at around 40 – 50 nm, which was dominant by nano-particles. The highest particle number concentrations were observed at berth while the largest particle mass emissions were observed during manoeuvring (see bottom graph). The PM1 emission factors measured with the DustTrak and DMS500 were in good agreement. It is also interesting to observe that all of the mass emitted even with HFO is carried by the particles in the size range below 1µm.

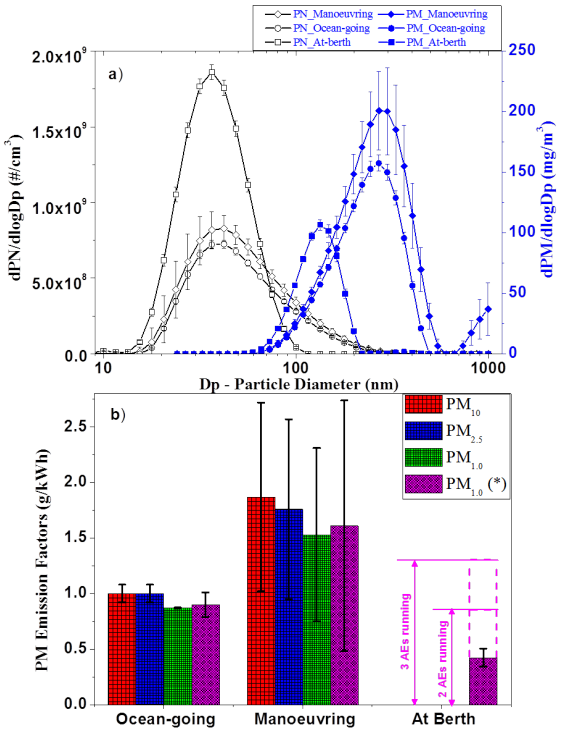

Figure 1. Top: Particle number and mass size distributions and Bottom: Particle mass concentrations at different operating conditions of the ship.

In addition to the average emission factors results on the real time (second by second) data on both particle and gasses for the whole voyage will be presented.

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Viana, M. et al. (2014) *Atmos. Environ.* **90,** 96-105.
Eyring, V. et al. (2010) *Atmos. Environ.* **44**(37), 4735-4771.